

Initial development and biomass partitioning of *Physocalymma scaberrimum* Pohl (Lythraceae) under different shading levelsDesenvolvimento inicial e partição de biomassa de *Physocalymma scaberrimum* Pohl (Lythraceae) sob diferentes níveis de sombreamentoMarco Bruno Xavier Valadão<sup>1</sup>, Ben Hur Marimon Junior<sup>\*2</sup>,  
Paulo Sérgio Morandi<sup>3</sup>, Simone Matias Reis<sup>3</sup>, Bianca de Oliveira<sup>1</sup>,  
Edmar Almeida de Oliveira<sup>3</sup> e Beatriz Schwantes Marimon<sup>2</sup>**Resumo**

O Bioma Cerrado perdeu extensas áreas de vegetação nativa ao longo das últimas décadas, fato que revela uma grande demanda por estudos que avaliem o potencial de espécies nativas para fins de reflorestamento. Diante dessa lacuna a ser preenchida, este trabalho teve como objetivo avaliar o desenvolvimento inicial de mudas de *Physocalymma scaberrimum* sob diferentes níveis de sombreamento, dado o potencial da espécie para uso em reflorestamento e recuperação de áreas degradadas. Este estudo foi conduzido em casa de vegetação com 0% (pleno sol), 30%, 50%, 70% e 90% de sombreamento. Foram avaliados os parâmetros de germinação, repartição de biomassa aérea e radicular, número de folhas, diâmetro do coleto, altura e índice de Dickson para qualidade de mudas (IQD) aos 150, 180, 210, 240 e 270 dias após a emergência das mudas. Os resultados foram comparados entre os tratamentos por meio de ANOVA e análise de regressão. Os maiores valores de diâmetro de coleto, número de folhas, biomassa total e radicular e IQD foram nos níveis intermediários de sombreamento. Para produção em larga escala de mudas de *P. scaberrimum* com boa qualidade recomendamos optar por níveis intermediários de sombreamento, preferencialmente a 50%.

**Palavras-chave:** Bioma cerrado, espécies nativas, luminosidade, qualidade de mudas, recuperação de área degradadas.

**Abstract**

The Cerrado Biome lost wide areas of native vegetation over the last decades. This fact reveals a high demand for studies that assess the potential of native species for reforestation purposes. Given this gap, this study aimed to evaluate the initial development of seedlings of *Physocalymma scaberrimum* under different shading levels, because of the potential of the species for reforestation and forest restoration. This research was conducted in a nursery at 0 % (full sun), 30%, 50%, 70% and 90% shading. Parameters were evaluated for germination, biomass and root, number of leaves, stem diameter, height and Dickson quality index of seedlings (DQI) at 150, 180, 210, 240 and 270 days after seedling emergence. The results between treatments were compared by ANOVA and regression analysis. The higher values of stem diameter, number of leaves, root and total biomass and DQI were found in the intermediate levels of shading. For large scale production of seedlings of *P. scaberrimum* with optimum quality we recommend the intermediate levels of shading, preferably 50 %.

**Keywords:** Cerrado biome, native species, brightness, seedling quality, restoration of degraded areas.

**INTRODUCTION**

The Cerrado is considered one of the world's hotspots for biodiversity preservation due to its major species richness, high biological endemism and high degree of threat (MYERS et al.,

2000). The intense land use for agriculture and livestock raising, including tree harvesting for charcoal production (FERREIRA et al., 2009), exposes the vulnerability of this biome, wherein several plant species are already under extinction risk (PAIVA, 2001).

<sup>1</sup>UNEMAT - Universidade do Estado de Grosso / Programa de Pós-graduação em Ecologia e Conservação. Caixa Postal 8, 78690-000 - Nova Xavantina, MT. E-mail: [marcobrunovaladiao@gmail.com](mailto:marcobrunovaladiao@gmail.com); [bibica\\_89@hotmail.com](mailto:bibica_89@hotmail.com).

<sup>2</sup>UNEMAT - Universidade do Estado de Grosso / Programa de Pós-graduação em Ecologia e Conservação. Caixa Postal 8, 78690-000 - Nova Xavantina, MT. Bolsista Produtividade em Pesquisa do CNPq. E-mail: [bhmjunior@gmail.com](mailto:bhmjunior@gmail.com).

<sup>3</sup>Rede BIONORTE - UNEMAT/UFAM. Caixa Postal 8, 78690-000 - Nova Xavantina, MT. E-mail: [morandibio@gmail.com](mailto:morandibio@gmail.com); [ednardinei@hotmail.com](mailto:ednardinei@hotmail.com); [matias.reis@yahoo.com.br](mailto:matias.reis@yahoo.com.br).

Moreover, the agricultural frontier in Brazil has already advanced beyond the Cerrado border, penetrating into the Amazon forest and creating a wide region known as 'Arc of Deforestation' (NOGUEIRA et al., 2008; NOGUEIRA et al., 2007). Owing to this scenario and the increasing concern with respect to environmental quality, there is a strong increase in demand for forest services and products, especially forest species seedling production destined for several purposes (ALVES et al., 2012). This demand pressure arouses the necessity for researches in order to optimize the low-cost production of seedlings with morphophysiological qualities capable of fulfilling the final objectives of the plantation (JOSÉ et al., 2005). Therefore, it is necessary to conduct studies about native forest species in the Cerrado Biome and in the southern border of the Amazon. The development of suitable techniques for seedling production (SOUCHIE et al., 2011), for instance, is a crucial stage in the restoration of degraded areas and for commercial plantations, or even for the implementation of systems of Agriculture-Livestock-Forest integration aiming at recovering the production capacity of the land.

Several studies have evaluated the early development of seedlings of different species in nursery, under the effect of controlled brightness, which gave different answers to the shading levels (MAZUCHOWSKI et al., 2007; NAKAZONO et al., 2001; 2007; SILVA et al., 2007). In most studies, the seedlings presented better response to intermediary brightness levels, with some variations in plant growth and vigor, and the best conditions were found between 30% and 70% shading. The light, as a primary source of energy related to photosynthesis, is one of the main factors affecting plant growth (CAMPOS; UCHIDA, 2002; DOUSSEAU et al., 2007), considering that distinct brightness levels cause morphologic and physiologic changes in the plant, with the adaptation driven by particular characteristics of each species in interaction with the environment (SCALON et al., 2003).

Brightness influence on seedlings can be determined through the index of seedling quality (NAKAZONO et al., 2001., DUTRA et al., 2012;). This indicator uses parameters such as height, stem diameter and biomass, analyzed alone or together, which can be revealing if applied in seedlings developed under similar envi-

ronmental conditions (FONSECA et al., 2002), as observed in studies by Azevedo et al. (2010), Chaves and Paiva (2004) and José et al. (2005). The formation of more vigorous seedlings provides a greater chance for success in the crop establishment and maximizes its growth while decreasing the transplantation time into the field (LIMA et al., 2008). The seedlings still must present greater shoot size and well-formed roots, so that they present higher surviving chances in the field (FERRAZ, 2011), especially under the seasonal conditions of the Cerrado Biome (MARIMON-JUNIOR et al. unpublished data).

Exotic species such as *Eucalyptus* spp. and *Tectona grandis* have guaranteed their own success in reforestations owing to many years of research and improvement of large scale production techniques of their propagules (FERMINO-JUNIOR et al., 2009; MACEDO et al., 2005; GOMES et al., 2002; GOMES et al., 1978; SANTOS et al., 2010). Nevertheless, the studies which take into account the plant growth performance in nursery and the silvicultural characteristics of native species are still scarce and not conclusive, despite some evidences of better root and shoot biomass production of seedlings at 50% shading (FELFILI et al., 1999). The continuous evaluation and follow-up of the processes of seedling production are important in order for us to learn about the physiologic responses of native species and to understand their ecology. Each response verified in these nursery experiments may also be used for the improvement of seedling production techniques, especially when quality criteria are taken into account.

The neotropical woody species *Physocalymma scaberrimum* Pohl must be included in studies regarding the development of native forest seedlings in nursery due to its major potential for timber production and for restoration of degraded areas, or still for Agriculture-Livestock-Forest integration (MARIMON-JUNIOR et al., unpublished data). According to the Lista de Espécies da Flora do Brasil 2013 (in <http://floradobrasil.jbrj.gov.br/2012>), this species is found in the North and Midwest of Brazil, as well as in the States of Acre, Pará, Goiás and Mato Grosso.

This work aimed at evaluating the early development of *Physocalymma scaberrimum* Pohl seedlings in order to understand how its seedlings grow under distinct shading levels, as there is a lack of nursery studies with most of native tree species in the Cerrado and Amazon. The ex-

periment is part of the “Matas de Galeria” Project (FAPEMAT 0738/2006), whose objective is to enhance knowledge with regard to the ecology and expertise of the main native woody species in the Cerrado Biome and pre-Amazonian transition forests. The main goal is to contribute to future *ex-situ* conservation actions for this species, as well as to sustainable activities and those regarding restoration of degraded areas or timber production and forest management.

## MATERIAL AND METHODS

The experiment was carried out between December 2008 and April 2009, in the forest nursery of the State University of Mato Grosso (UNEMAT), Nova Xavantina campus, Mato Grosso State. The climate in the region is Aw, according to Köppen’s classification, with two well-defined seasons: one dry, from April to September, and another rainy, from October to March (SILVA et al., 2008), with annual average rainfall ranging from 1,300 to 1,500 mm (MARIMON et al., 2010).

Healthy seeds without signs of predation were collected in a preserved gallery forest in the Bacaba Municipal Park, municipality of Nova Xavantina-MT. The seeds were sown in black 15 x 30 cm polyethylene bags with lateral holes for water drainage. The substrate utilized was a mixture of weathered wood sawing and Red Oxisol in a 2:1 ratio, respectively. The fertilization was done with 350 g m<sup>-3</sup> of NPK 4-30-16 granular fertilizer and pH adjustment with 980 g m<sup>-3</sup> of lime to improve the substrate (Table 1) and provide the basic nutritional requirements for *P. scaberrimum*, a tree species that occurs in soils with medium fertility in the Cerrado Biome. The substrate was mixed in an electric mixer for perfect homogenization. An extra dose of 0.5 g triple superphosphate was added in each bag so as to compensate the P fraction of the substrate inhibited by the alkaline action of the limestone.

The seeds of *P. scaberrimum* were submitted to the following shading treatments described by Marimon et al. (2008): 0% (full sun), 30%,

50%, 70% and 90%, covered by a nylon shade-screen. Fifty plants were assessed in each shading level. The shading levels were established by measurements of the photosynthetic active radiation (PAR) in each treatment, by three measurements in the morning and three in the afternoon, using a LI-190 S quanta sensor (LI-COR Inc., USA). We used a no shaded control point to determine the measure of full sun. The levels of 30, 50 and 70% were obtained by using commercial screen Sombrite® and 90% overlapping of two screens with 30% and 20% shading, all shading levels were confirmed by the inverse of PAR proportional comparison with the control (full sun). Daily irrigations were applied by micro spray, with daily application rate adjusted according to the microclimatic conditions assessed by the meteorological station of UNEMAT – Nova Xavantina (OMM: 83319), latitude -14,7°, longitude -52,35°, altitude 316m .

For each treatment we registered the number of germinated seeds within a period of 22 days and later evaluated the percentage and Germination Velocity Index (GVI), we considered germinated seeds that showed full stretch hypocotyl over the substrate. The germination velocity calculation was performed according to Maguire (1962), where:  $GVI = S (Gi/ni)$ ;  $Gi$  = number of germinated seeds and  $ni$  = counting day.

Seedling height was measured from the base to the apical bud by a clear millimeter rule, with point zero placed at the base of the plant. Stem diameter was measured by a digital caliper (0.02 mm precision) positioned at the base of the stem. The number of leaves was manually counted, considering only the fully-expanded leaves. These parameters were first assessed 150 days after seedling emergence (DAE) and, afterwards, at 180, 210, 240 and 270 DAE. At the end of the experiment (270 DAE), ten seedlings of each treatment were used to assess root and shoot dry biomass. The roots were separated from the substrate by a water wash. Root and shoot parts were separated, identified, dried in oven at 80°C until constant weight, and then weighed on a precision scale.

**Table 1.** Chemical characteristics of the substrate used to produce *Physocalymma scaberrimum* seedlings in forest nursery.

**Tabela 1.** Atributos químicos do substrato utilizado na produção de mudas de *Physocalymma scaberrimum* em viveiro florestal.

pH (H <sub>2</sub> O)	P	K	Ca	Mg	Al	SB	C.E.C.	O.M.	(V)	Ca/Mg
	mg dm <sup>-3</sup>		cmol <sub>c</sub> dm <sup>-3</sup>					(%)		
6,7	24,9	167	1,6	0,53	0,0	2,9	3,6	10,2	80,5	3,01

SB = sum of bases; CEC = cation exchange capacity; O.M. = organic matter; V = base saturation

In order to determine the differences regarding quality/size in the seedlings development, the quality standard was evaluated through Dickson quality index (DQI) (DICKSON et al., 1960), through the formula:  $DQI = TDM / ((H/D) + (SDM/RDM))$ , where TDM = Total dry mass (g); H = shoot height (cm); D = stem diameter (mm); SDM = Shoot dry mass (g); and RDM = root dry mass. This index weighs the root/shoot ratio and the allometric relations between height and diameter, once the etiolated seedlings or those with lower root development must be considered as low-quality due to their stress sensibility in field conditions. We also calculated the relationship between height and shoot dry mass (H/SDM).

The differences in seedlings' development parameters among treatments were tested by analysis of variance (One-Way ANOVA) followed by Tukey's test, whenever there was difference between averages at the 5% significance level. Data normality was verified by Shapiro-Wilk's test and homogeneity of variances by Levene's test. For samples whose Levene's value was lower than 0.05, data were transformed by Log10. If the presuppositions were not fulfilled, the Kruskal-Wallis' test was carried out (SIEGEL; CASTELLAN-JÚNIOR, 1988), followed by Dunnett test at 5% probability. In order to verify the relation between brightness and diameter, height and number of leaves a regression analysis was done; the model which best fitted the dataset was used. The analyses were carried out through the software BioEstat 5.0 (AYRES et al., 2007).

## RESULTS

### Germination

The results for Germination Velocity Index (GVI) and the percentage of germination of *Physocalymma scaberrimum* seeds are presented in Table 2. The *P. scaberrimum* seeds were sown immediately after harvest and began the germination process on the third day, up to 18 days after sowing in all treatments. The GVI and the percentage of germinated seeds were high in all treatments but not influenced by shading levels.

**Table 2.** Effect of different shading levels in Germination Speed Index (GVI) and total germination (%) for *Physocalymma scaberrimum* seeds in forest nursery.

**Tabela 2.** Efeito dos diferentes níveis de sombreamento no Índice de Velocidade de Germinação (IVG) e germinação total (%) para sementes de *Physocalymma scaberrimum* em viveiro florestal.

Treatment	GVI	(%) Germination
0%	0.299a	100a
30%	0.426a	100a
50%	0.340a	100a
70%	0.330a	100a
90%	0.284a	92a

Means followed by the same letter do not differ significantly by Tukey and Dunnett tests at 5% probability.

### Height

Shading levels influence on *P. scaberrimum* seedlings height (cm) followed a similar pattern. The 30%, 50% and 70% shading levels presented the highest mean height values and did not differ from each other in any of the five sampling periods (Table 3). The seedlings submitted to extreme brightness (full sun) and shading (90%) levels showed average heights significantly lower than the other treatments, but did not statistically differ from each other (Table 3).

### Diameter

Stem diameter also showed a similar pattern of performance under intermediary shading levels (30, 50 and 70%), not significantly differing from each other in any of the evaluations (Table 3). Only the full-sun treatment did not differ from the 30% shading treatment in the evaluation at 180 DAE and from that of 70% shade at 240 DAE.

The seedlings in the highest shading (90%) treatment presented average stem diameter values significantly lower than all other treatments at 180, 210 and 240 DAE (Table 3). We found significant differences at 210, 240 and 270 DAE for the 50% shading in the regression tests for stem diameter in relation to the shading levels (Figure 1). The better performance of the seedlings under 50% shading can be observed, from the middle to the end of the experiment.

### Number of leaves

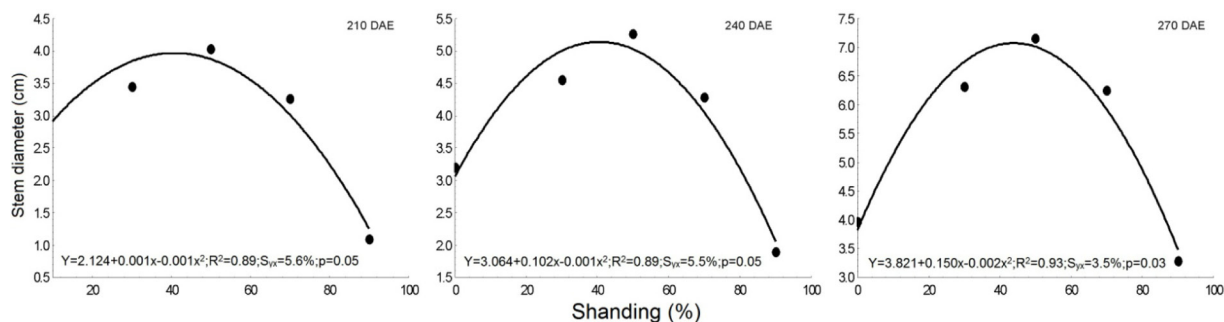
The number of leaves in the *P. scaberrimum* seedlings followed a pattern of better response to the intermediary shading levels throughout time, presenting significant higher number of leaves in the 50% treatment compared to the others in the evaluation at 180 DAE (Table 3).

**Table 3.** Effects of different levels of shading in height (cm), stem base diameter (mm) and number of leaves at 150, 180, 210, 240 e 270 days after seedling emergence (DAE) from *Physocalymma scaberrimum* in forest nursey.

**Tabela 3.** Efeitos dos diferentes níveis de sombreamento na altura (cm), diâmetro do coleto (mm) e número de folhas aos 150, 180, 210, 240 e 270 dias após emergência (DAE) de *Physocalymma scaberrimum* em viveiro florestal.

DAE	Treatment	Height (cm)	Stem base diameter (mm)	Number of leaves
150	(0%)	4.82b	0.83b	10.36b
	(30%)	7.31a	1.22a	12.12b
	(50%)	9.31a	1.49a	20.74a
	(70%)	7.59a	1.33a	14.72a
	(90%)	4.07b	0.64b	12.22b
		$F_{(4, 240)} = 18.74, p < 0.01$	$H_{(4, 245)} = 60.34, p < 0.01$	$H_{(4, 245)} = 56.42, p < 0.01$
180	(0%)	7.38b	1.56b	23.71b
	(30%)	10.65a	2.09ab	23.25b
	(50%)	12.00a	2.65a	44.53a
	(70%)	11.94a	2.53a	26.64b
	(90%)	6.00b	0.95c	15.59c
		$H_{(4, 247)} = 55.43, p < 0.01$	$F_{(4, 240)} = 22.93, p < 0.01$	$H_{(4, 247)} = 56.63, p < 0.01$
210	(0%)	9.84b	2.25b	39.10b
	(30%)	13.71a	3.45a	37.61b
	(50%)	14.18a	4.04a	55.98a
	(70%)	14.51a	3.28a	43.29ab
	(90%)	8.22b	1.09c	23.94c
		$H_{(4, 244)} = 43.76, p < 0.01$	$F_{(4, 239)} = 43.54, p < 0.01$	$H_{(4, 244)} = 39.71, p < 0.01$
240	(0%)	9.26b	3.21b	36.85b
	(30%)	17.83a	4.55a	59.67a
	(50%)	15.18a	5.26a	60.09a
	(70%)	18.45a	4.29ab	55.00a
	(90%)	8.02b	1.89c	28.63b
		$F_{(4, 237)} = 64.65, p < 0.01$	$F_{(4, 237)} = 27.65, p < 0.01$	$F_{(4, 236)} = 16.43, p < 0.01$
270	(0%)	10.48b	4.00b	26.08c
	(30%)	21.36a	6.32a	69.45a
	(50%)	19.79a	7.16a	62.24a
	(70%)	19.72a	6.27a	58.58a
	(90%)	13.60b	3.28b	36.80b
		$F_{(4, 236)} = 18.97, p < 0.01$	$F_{(4, 236)} = 22.91, p < 0.01$	$F_{(4, 236)} = 26.91, p < 0.01$

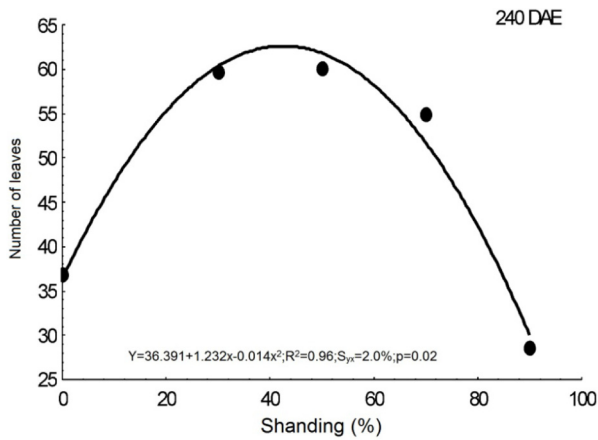
Means followed by the same letter do not differ significantly by Tukey and Dunnett tests at 5% of probability.



**Figure 1.** Effect of shading levels on stem diameter of *Physocalymma scaberrimum* seedlings in forest nurser at 210, 240 and 270. DAE = days after seedling emergence.

**Figura 1.** Efeito de níveis de sombreamento sobre o diâmetro do coleto em mudas de *Physocalymma scaberrimum* em viveiro florestal aos 210, 240 e 270 DAE = dias após a emergência.

The regression analysis at 240 DAE showed a significant quadratic pattern (Figure 2), when the seedlings reached an average value of nearly 60 leaves in 50% shading.



**Figure 2.** Effect of shading levels at 240 DAE on the amount of leaves produced by *Physocalymma scaberrimum* seedlings in a forest nursery.

**Figura 2.** Efeito de níveis de sombreamento aos 240 DAE sobre a quantidade de folhas produzidas pelas mudas de *Physocalymma scaberrimum* em viveiro florestal.

### Biomass

The root/shoot relation (RSR) was highest in the 30% (1.42) shading treatment (Table 4), but did not significantly differ from the 50% (1.27) and 70% (0.90) treatments. Such situation of  $RSR < 1$  can be easily found in etiolated seedlings, mainly under intense shading as observed in this study, wherein seedlings in the 70 and 90% treatment showed 0.9 and 0.72 values, respectively.

The 50% shading showed significantly higher values than full-sun (0%) and 90% shading treatments in all biomass parameters assessed (root, shoot, total and root/shoot relation) (Ta-

ble 4). Furthermore, the pattern of higher means of total biomass at intermediary levels was maintained, with the highest value registered for the 50% shading treatment, which did not significantly differ from 30 and 70% treatments. The regression analyses (Table 5) for root dry mass and total biomass (Figure 3) confirmed the best performance at intermediary shading levels.

**Table 4.** Mean values of the dry weight of root, stem, total and root/shoot ratio of *Physocalymma scaberrimum* seedlings at 270 DAE under different levels of shading in a forest nursery.

**Tabela 4.** Valores médios do peso de massa seca da raiz, caule, total e relação raiz/parte aérea das plântulas de *Physocalymma scaberrimum* aos 270 DAE sob diferentes níveis de sombreamento em viveiro florestal.

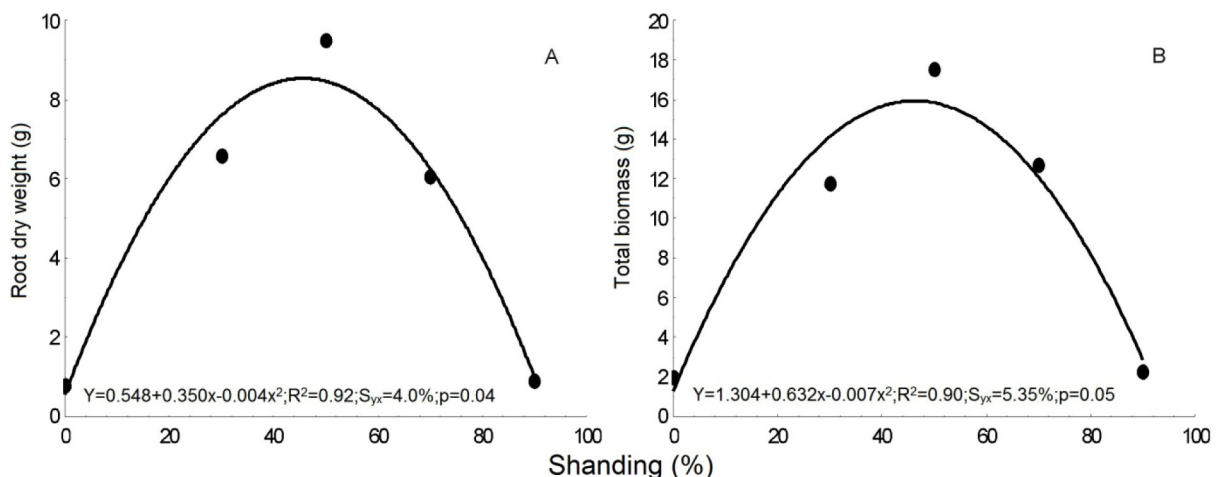
Treatment	Weight dry biomass (g)			Ratio root/shoot
	Root	Stem	Total	
0%	0,80a	1,18a	1,98a	0,56a
30%	6,59b	5,20ab	11,79b	1,42b
50%	9,52b	8,01b	17,53b	1,27b
70%	6,07b	6,63b	12,70b	0,90ab
90%	0,91a	1,35a	2,26a	0,72a

Means followed by the same letter do not differ significantly by Tukey and Dunnett tests at 5% probability.

### Dickson quality index (DQI)

Table 6 presents the mean values of the relationship between height and stem diameter (H/SD), height and shoot dry mass (H/SDM), dry weight of shoot and root dry mass (SDM/RDM) and Dickson Quality Index (DQI) according to the levels of shading.

The relation H/SDM and SDM/RDM of Dickson Quality Index, showed the lower values at 30, 50 and 70% shading levels. *P. scaberrimum* seedlings submitted to 50% shading presented higher DQI (Table 6), but with average values not differing from 30 and 70% shading.



**Figure 3.** Effect of shading levels on root dry biomass (A) and (B) total biomass in *Physocalymma scaberrimum* seedlings at 270 DAE in a forest nursery.

**Figura 3.** Efeito de níveis de sombreamento sobre a biomassa seca da raiz (A), e total (B) em mudas de *Physocalymma scaberrimum* aos 270 DAE em viveiro florestal.

**Table 5.** Bivariate correlation between different levels of shading on the development of *Physocalymma scaberrimum* seedlings, in forest nursery. DAE=days after seedling emergence, shoot dry mass (SDM), H (high), D (diameter), RDM (root dry mass), DQI (Dickson quality index), TDM (total dry matter) r = correlation coefficient, p = significance level.

**Tabela 5.** Correlação bivariada entre diferentes níveis de sombreamento sobre o desenvolvimento de mudas de *Physocalymma scaberrimum* em viveiro florestal. DAE=dias após a emergência; MSPA=massa seca da parte aérea; H = altura; D = diâmetro; MSR = massa seca da raiz, IQD = índice de qualidade de Dickson; MST = massa seca total; r = coeficiente de correlação; p = nível de significância.

Bivariate correlation						
DAE	Height (cm)		Stem base diameter (mm)		Number of leaves	
	r	p	r	p	r	p
150	0,83	0,086	0,80	0,099	0,11	0,446
180	0,75	0,128	0,60	0,201	0,03	0,487
210	0,77	0,115	0,89	0,052	0,24	0,381
240	0,59	0,210	0,89	0,051	0,96	0,018
270	0,88	0,057	0,93	0,032	0,88	0,061
Root Weight	0,92	0,037	-	-	-	-
Stem Weight	0,83	0,086	-	-	-	-
Root/SDM	0,67	0,165	-	-	-	-
H/D	0,28	0,362	-	-	-	-
H/SDM	0,84	0,082	-	-	-	-
SDM/RDM	0,66	0,168	-	-	-	-
DQI	0,67	0,164	-	-	-	-
TDM	0,90	0,049	-	-	-	-

Means followed by the same letter do not differ significantly by Tukey and Dunnett tests at 5% probability.

**Table 6.** Mean values of the relations height/stem diameter (H/SD), height/shoot dry mass (H/SDM), shoot dry mass/root dry mass (SDM/RDM) and DQI (Dickson quality index) of *Physocalymma scaberrimum* seedling at 270 DAE under different levels of shading, in a forest nursery.

**Tabela 6.** Valores médios das relações altura/diâmetro do coleto (H/D), altura/massa seca parte aérea (H/MSPA), massa seca parte aérea/massa seca da raiz (MSPA/MSR) e índice de qualidade de Dickson (IQD) de plântulas de *Physocalymma scaberrimum* aos 270 DAE, sob diferentes níveis de sombreamento, em viveiro florestal.

Treatment	H/D	H/SDM	SDM/RDM	DQI
0%	2,84c	21,39a	1,48a	0,46a
30%	3,50b	7,86b	0,79b	2,66b
50%	2,72c	3,30b	0,84bc	4,75b
70%	3,30b	3,58b	1,09abc	2,88b
90%	4,48a	12,18a	1,49ac	0,38a

Means followed by the same letter do not differ significantly by Tukey and Dunnett tests at 5% probability.

## DISCUSSION

### Germination

The sensitivity of the tree seed to light is variable according to species. There are seed whose germination is affected positively or negatively by light and some are indifferent to it, depending on the physiological sensibility of the plant (AGUIAR et al., 1993). In our study, shading levels did not influence the percentage of seedling emergence, which presented little response to sun light and poor germination sensitivity of the species to this environmental factor.

On the other hand, seeds of *Diplusodon virgatus* Pohl, species which also belongs to the Lythraceae family, showed a positive photoblastic response in seeds that were germinated at longer photoperiods in the study conducted by Cesarino et al. (1999) under controlled conditions. These results demonstrate the relative variations in germination response to light among some tree species.

### Height

Rosa et al. (2009), who assessed the development of *Schizolobium amazonicum* Huber ex Ducke seedlings, found better performance of the species also at intermediate shading. Although they worked with a different family than the present study, the authors highlighted that the height gain due to the increase in the intensity of shading is very common in the juvenile phase of Amazonian forest species.

Height was influenced in the study of Maranhão and Paiva (2012); which evaluated the effect of different organic substrates also in seedlings of *P. scaberrimum*. Mexal and Landis (1990) emphasized that shoot height provides a good estimate of the initial development of seedlings in the field. However, both extremes (full sun and full shade) affected *P. scaberrimum* growth in height in the present study (Table 3), supporting the idea that its use in restoration of degraded areas could be used in the plantation in advanced stages of succession.

## Diameter

The intermediate levels of shade also favored the gain in diameter of *P. scaberrimum* seedlings. According to Larcher (2000), if there is no drastic change on the ground conditions, is kept linear logarithmic correlation between the mass of the stem and root mass (allometric growth).

The significance pattern of the regression curves at 210, 240 and 270 days after seedling emergence, demonstrates the importance of this parameter. According to Gomes and Paiva (2004), the stem diameter is strongly correlated with other characteristics of seedlings, explaining 70-80% of differences in dry weight matter between them. In a study conducted by Rego and Possamai (2006), with *Cariniana legallii* (Mart.) Kuntze seedlings in the city of Colombo in Paraná state, they reduced the percentage of photosynthetically active radiation; which affected diameter growth resulting in a less developed the root system. The reduction of diameter in seedlings may affect their growth performance, condition clearly observed by reducing the Dickson quality index observed in studies with other forest species under controlled shading experiments (Marimon-Junior et al., unpublished data).

## Number of leaves

The low tolerance at highest shading levels was also pointed out by Câmara and Endres (2008) in Maceió, state of Alagoas with *Mimosa caesalpiniiifolia* Benth seedlings submitted to 92% shading, and with highest number of leaves in seedlings exposed to 50% shading. The species *Simarouba amara* assessed by Azevedo et al. (2010) in Manaus state of Amazonas presented similar performance. This response is similar to *Hymenaea courbaril*, a shade-tolerant tree species tested in nursery by Marimon-Junior et al. (unpublished data).

Since the intermediate amount of light is responsible for the level of chlorophyll in the leaves, this condition tends to increase levels of the pigment in *a* and *b* forms (MARTINAZZO et al., 2007). However, the content of chlorophyll *b* is better correlated to shaded environments (ENGEL; POGGIANI, 1991), since it allows the capture of energy in other wavelengths than chlorophyll *a*, in order to maintain the nutritional equilibrium of the plant (WHATLEY; WHATLEY, 1982). We did not evaluate this condition, but new studies must be conducted to investigate whether the higher levels of shade

are compensated or not by an increase in *b* chlorophyll concentrations in the leaves.

## Biomass

The root/shoot relation (RSR) is an important quality criteria for seedlings, since those with a more developed shoot portion than the root ( $RSR < 1$ ) can be more sensitive to water stress under conditions of high air temperature and low relative humidity during dry seasons (LARCHER, 2000), as found in the Cerrado Biome (SILVA et al., 2008).

Similar results were observed in young seedlings of *Brosimum rubescens* Taub. from seeds collected in a transitional Amazonia/Cerrado monodominant forest in study conducted by Marimon et al. (2008). The authors emphasize that higher investment in root biomass under low-shading conditions is evidence that root development is necessary for seedling survival in natural conditions of high brightness (large gaps) and seasonal water deficit.

Although the parameter of total biomass has shown a significant correlation with the levels of shading, we used the biomass partitioned tests in order to analyze each part of the plant separately. This is because when a pattern of quality is not based on partitioned plant, but only on the total weight, it weakens the recommendations.

## Dickson quality index (DQI)

Based on the fact that the lowest values of allometric relations are those in which the divisor is height ( $H/SDM$  and  $SDM/RDM$ ), we affirm that *P. scaberrimum* tends to invest more in crown-related volume than in total height under intermediary brightness conditions. This response may possibly be due to the fact that these conditions are similar to those found in the natural environment of this species, thus more suitable for this growth pattern. In this case, seedling quality tends to be better since investment in root follows the highest vegetative effort of the plant in the canopy total volumetric formation (DICKSON et al., 1960).

Similar results were found in studies with seedlings of *Senna macranthera* (Collad.) Irwin et Barn conducted in Viçosa, state of Minas Gerais by Chaves and Paiva (2004). The authors verified decreases in the  $H/SDM$  relation when shading periods were increased. The lowest values that we found for such relationships were preponderant for the higher DQI presented by seedlings of *P. scaberrimum* at 50% shading. Although it did



not differ from 30 to 70%, this level provided concrete information about the quality standards of seedlings brought to the field. Azevedo et al. (2010) also obtained higher DQI values for *Simarouba amara* with 50% shading depending on the relationship between height and stem diameter at this intermediate level.

Large-scale seedling production requires maximum knowledge with respect to the needs of the species in the region (e.g. climate conditions) in which the work is being conducted. In the case of *P. scaberrimum* in this study, it is clear that the intermediary shading intensities, emphasizing the 50% level, is an important recommendation for seedling production in the region, considering the lack of studies which compile precise information with respect to the native species of the Cerrado Biome and pre-Amazonian transition, a zone submitted to strong seasonal dry conditions.

## CONCLUSIONS

The results obtained in this study show that better development and quality in seedling production occurs at 50% shading, with low performance at extreme levels (full sun and 90%), evidencing low plasticity in the physiologic responses of *P. scaberrimum* to light extremes. For the production of *P. scaberrimum* seedlings, on a large scale with satisfactory quality, we recommend the use of intermediary shading levels, preferably 50%. These levels may be suitable to obtain more vigorous and, possibly, resistant seedlings for field cultivation under the seasonal dry conditions of the Cerrado Biome and the southern border of the Amazon forest.

## ACKNOWLEDGEMENTS

To FAPEMAT - Fundação de Amparo à Pesquisa do Estado de Mato Grosso, which enabled the Matas de Galeria Project, to the Programa de Pós-graduação em Ecologia e Conservação - UNEMAT, and the entire staff of the Laboratório de Ecologia Vegetal, at Universidade do Estado de Mato Grosso, Nova Xavantina campus.

## REFERENCES

- AGUIAR, I. B.; PIÑA-RODRIGUES, F. C. M.; FIGLIOLIA, M. B. *Sementes Florestais Tropicais*. 1.ed. Brasília: Associação Brasileira de Tecnologia de Sementes, 1993. v. 1. 350 p.
- ALVES, A. S.; OLIVEIRA, L. S. B.; ANDRADE, L. A.; GONÇALVES, G. S.; SILVA, J. M. Produção de mudas de angico em diferentes tamanhos de recipientes e composições de substratos. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, Mossoró, v. 7, n. 2, p. 39-44, 2012.
- AYRES, M.; AYRES JR., M.; AYRES, D. L.; SANTOS, A. A. S. *BioEstat 5.0: aplicações estatísticas na área das ciências bio-médicas*. Belém: Sociedade Civil de Mamirauá, 2007. 364 p.
- AZEVEDO, I. M. G.; ALENCAR, R. M.; BARBOSA, A. P.; ALMEIDA, N. O. Estudo do crescimento e qualidade de mudas de marupá (*Simarouba amara* Aubl.) em viveiro. *Acta Amazonica*, Manaus v. 40, n. 1, p. 157-164, 2010.
- CÂMARA, C. A.; ENDRES, L. Desenvolvimento de mudas de duas espécies arbóreas: *Mimosa caesalpiniiifolia* Benth. e *Sterculia foetida* L. sob diferentes níveis de sombreamento em viveiro. *Floresta*, Curitiba, v. 38, n. 1, p. 43-52, 2008.
- CAMPOS, M.A.A.; UCHIDA, T. Influência do sombreamento no crescimento de mudas de três espécies amazônicas. *Pesquisa agropecuária brasileira*, Brasília, v.37, n.3, p.281-288, 2002.
- CESARINO, F.; ARAUJO, J. E.; ZAIDAN, L. B. P. Germinação de sementes e crescimento de plantas de *Diplusodon virgatus* Pohl, Lythraceae. *Acta Botanica Brasilica*, São Paulo, v. 13, n. 3, p. 349-356, 1999.
- CHAVES, A. S.; PAIVA, H. N. Influência de diferentes períodos de sombreamento sobre a qualidade de mudas de fedegoso (*Senna macranthera* (Collad.) Irwin et Barn.). *Scientia Forestalis*, Piracicaba, n. 65, p. 22-29, 2004.
- DICKSON, A.; LEAF, A. L.; HOSNER, J. F. Quality appraisal of white spruce and white pine seedling stock in nurseries. *Forest Chronicles*, Ontário, v. 36, p. 10-13, 1960.
- DOUSSEAU, S.; ALVARENGA, A. A.; SANTOS, M. O.; ARANTES, L. O. Influência de diferentes condições de sombreamento sobre o crescimento de *Tapirira guianensis* Alb. *Revista Brasileira de Biociências*, Porto Alegre, v. 5, n. 2, p. 477-479, 2007.
- DUTRA, T. R.; GRAZZIOTTI, P. H.; SANTANA, R. C.; MASSAD, M. D. Desenvolvimento inicial de mudas de copaíba sob diferentes níveis de sombreamento e substratos. *Revista Ciência Agronômica*, Fortaleza, v. 43, n. 2, p. 321-329, 2012.

- ENGEL, V. L.; POGGIANI, F. Estudo da concentração de clorofila nas folhas e seu espectro de absorção de luz em função do sombreamento em mudas de quatro espécies florestais nativas. **Revista Brasileira de Fisiologia Vegetal**, Campinas, v. 3, n. 1, p. 39-45, 1991.
- FELFILI, J. M.; HILGBERT, L. F.; FRANCO, A. C.; SILVA, J. C. S.; REZENDE, A. V.; NOGUEIRA, M. V. P. Comportamento de plântulas de *Sclerobium paniculatum* Vog. var. *rubinosum* (Tul.) Benth. sob diferentes níveis de sombreamento, em viveiro. **Revista Brasileira de Botânica**, São Paulo, v. 22, n. 2, p. 297-301, 1999.
- FERMINO-JUNIOR, P. C. P.; NAGAO, E. O.; SCHERWINSKI-PEREIRA, J. E. Estabelecimento, germinação e multiplicação in vitro de teca (*Tectona grandis* L.f.) a partir de genótipos da Amazônia Sul-Occidental. **Scientia Forestalis**, Piracicaba, v. 37, n. 84, p. 427-435, 2009.
- FERRAZ, A. V.; ENGEL, V. L. Efeito do tamanho de tubetes na qualidade de mudas de Jatobá (*Hymenaea courbaril* L. var. *stilbocarpa* (Hayne) Lee et Lang.), Ipê-amarelo (*Tabebuia chrysostricha* (Mart. ex DC.) Sandl.) e Guaruaia (*Parapiptadenia rigida* (Benth.) Brenan). **Revista Árvore**, Viçosa, v. 35, n. 3, p. 413-423, 2011.
- FERREIRA, M. E.; MIZIARA, F.; FERREIRA JR., L. G.; RIBEIRO, F. L.; FERREIRA, N. C. Ativos ambientais do bioma cerrado: uma análise da cobertura vegetal nativa e sua relação com o preço da terra no estado Goiás. **Revista Brasileira de Cartografia**, Rio de Janeiro, n. 61/1, p. 37-50, 2009.
- FONSECA, E. P.; VALÉRI, S. V.; MIGLIORANZA, E.; FONSECA, N. A. N.; COUTO, L. Padrão de qualidade de mudas de *Trema micranta* (L.) Blume, produzidas sob diferentes períodos de sombreamento. **Revista Árvore**, Viçosa, v. 26, n. 4, p. 515-523, 2002.
- GOMES, J. M.; COUTO, L.; LEITE, H. G.; XAVIER, A.; GARCIA, S. L. R. Parâmetros morfológicos na avaliação da qualidade de mudas de *Eucalyptus grandis*. **Revista Árvore**, Viçosa, v. 26, n. 6, p. 655-664, 2002.
- GOMES, J. M.; FERREIRA, M. G. M.; BRANDI, R. M.; NETO, F. P. Influência do sombreamento no desenvolvimento de *Eucalyptus grandis* Hill ex Maiden. **Revista Árvore**, Viçosa, v. 2, n.1, p. 68-75, 1978.
- GOMES, J. M.; PAIVA, H. N. **Viveiros Florestais (Propagação Sexuada)**. 3.ed., Viçosa: UFV. 2004. 116 p.
- JOSÉ, A. C.; DAVIDE, A. C.; OLIVEIRA, S. L. Produção de mudas de aroeira (*Schinus terebinthifolius* Raddi) para recuperação de áreas degradadas pela mineração de bauxita. **Cerne**, Lavras, v. 11, n. 2, p. 187-196, 2005.
- LARCHER, W. **Ecofisiologia Vegetal**. São Carlos: RIMA. 2000. 531 p.
- LIMA, J. D.; SILVA, B. M. S.; MORAES, W. S.; DANTAS, V. A. V.; ALMEIDA, C. C. Efeitos da luminosidade no crescimento de mudas de *Caesalpinia ferrea* Mart. Ex Tul. (Leguminosae, Caesalpinoideae). **Acta Amazonica**, Manaus, v. 38, n. 1, p. 5-10, 2008.
- MACEDO, R. L. G.; GOMES, J. E. VENTURIN, N.; SALGADO, B. G. Desenvolvimento inicial de *Tectona grandis* L.f. (teca) em diferentes espaçamentos no Município de Paracatu, MG. **Cerne**, Lavras, v. 11, n. 1, p. 61-69, 2005.
- MAGUIRE, J. A. Speed of germination-aid in selection and evaluation for seedling emergence and vigor. **Crop Science**, Madison, v. 31, p. 176-177, 1962.
- MARANHO, Á. S.; PAIVA, A. V. Produção de mudas de *Physocalymma scaberrimum* Pohl em substratos compostos por diferentes porcentagens de resíduo orgânico de açaí. **Floresta**, Curitiba, v. 42, n. 2, p. 399-408, 2012.
- MARIMON, B. S.; FELFILI, J. M.; LIMA, E. S.; DUARTE, W. M. G.; MARIMON-JUNIOR, B. H. Environmental determinants for natural regeneration of gallery forest at the Cerrado Amazonia boundaries in Brazil. **Acta Amazonica**, Manaus, v. 40, n. 1, p. 107-118, 2010.
- MARIMON, B. S.; FELFILI, J. M.; MARIMON-JUNIOR, B. H.; FRANCO, A.C.; FAGG, C. W. Desenvolvimento inicial e partição de biomassa de *Brosimum rubescens* Taub. (Moraceae) sob diferentes níveis de sombreamento. **Acta Botânica Brasilica**, São Paulo, v. 22, n. 4, p. 941-953. 2008.
- MARTINAZZO, E. G.; ANESE, S.; WANDSCHEER, A. C. D.; PASTORINI, L. H. Efeito do Sombreamento sobre o Crescimento e Teor de Clorofila Foliar de *Eugenia uniflora* Linn (Pitanga)-Família Myrtaceae. **Revista Brasileira de Biociências**, Porto Alegre, v. 5, n. S2, p. 162-164, 2007.

- MAZUCHOWSKI, J. Z.; SILVA, E. T.; MACCARI JR., A. Efeito da luminosidade e da adição de nitrogênio no crescimento de plantas de *Ilex paraguariensis* St. Hil. **Revista Árvore**, Viçosa, v. 31, n. 4, p. 619-627, 2007.
- MEXAL, J. L.; LANDIS, T. D. Target seedling concepts: height and diameter. In: TARGET SEEDLING SYMPOSIUM, COMBINED MEETING OF THE WESTERN FOREST NURSERY ASSOCIATIONS. 1990, Roseburg. **Proceedings...** Fort Collins: USDA, Forest Service, 1990. p. 17-35.
- MYERS, N.; MITTERMEIER, R. A.; MITTERMEIER, C. G.; FONSECA, G. A. B.; KENT, J. Biodiversity hotspots for conservation priorities. **Nature**, New York, v. 403, p. 853-858, 2000.
- NAKAZONO, E. M.; COSTA, M. C.; FUTATSUGI, K.; PAULILO, M. T. S. Crescimento inicial de *Euterpe edulis* Mart. em diferentes regimes de luz. **Revista Brasileira de Botânica**, São Paulo, v. 24, n. 2, p. 173-179, 2001.
- NOGUEIRA, E. M.; FEARNESIDE, P. M.; NELSON, B. W.; FRANÇA, M. B. Wood density in forests of Brazil's 'arc of deforestation': Implications for biomass and flux of carbon from land-use change in Amazonia. **Forest Ecology and Management**, Amsterdam, n. 248, n. 3, p. 119-135, 2007.
- NOGUEIRA, E.M.; NELSON, B.W.; FEARNESIDE, P.M.; FRANÇA, M.B.; OLIVEIRA, A.C.A. Tree height in Brazil's 'arc of deforestation': Shorter trees in south and southwest Amazonia imply lower biomass. **Forest Ecology and Management**, Amsterdam, n. 255, n. 7, p. 2963-2972, 2008.
- PAIVA, H. N.; JACOVINE, L. A. G.; RIBEIRO, G. T.; TRINDADE, C. **Cultivo de Eucalipto em propriedades rurais**. Viçosa: Aprenda Fácil, 2001. 138 p.
- REGO, G. M.; POSSAMAI, E. Efeito do sombreamento sobre o teor de clorofila e crescimento inicial do Jequitibá-Rosa. **Boletim de Pesquisa Florestal**, Colombo, v. 53, p. 179-194, 2006.
- ROSA, L. S.; VIEIRA, T. A.; SANTOS, D. S.; SILVA, L. C. B. Emergência, crescimento e padrão de qualidade de mudas de *Schizolobium amazonicum* Huber ex Ducke sob diferentes níveis de sombreamento e profundidade de semeadura. **Revista de Ciências Agrárias**, Belém, n. 52, p. 87-98, 2009.
- SANTOS, R. F.; MORAIS, F.; BORSOI, A.; SECCO, D.; MOREIRA, G. C. Níveis de sombreamento na produção e desenvolvimento de mudas *Eucalyptus grandis* Hill ex Maiden. **Revista Brasileira de Tecnologia Aplicada nas Ciências Agrárias**, Campina Grande, v. 3, n. 3, p. 201-206, 2010.
- SCALON, S. P. Q.; MUSSURY, R. M.; RIGONI, M. R.; SCALON FILHO, H. Crescimento inicial de mudas de *Bombacopsis glabra* (Pasq.) A. Robyns sob condições de sombreamento. **Revista Árvore**, Viçosa, v. 27, n. 6, p. 753-758, 2003.
- SIEGEL, S.; CASTELLAN, N. J. **Nonparametric Statistics for the Behavioral Sciences**. 2.ed. New York: McGraw-Hill, 1988. 399 p.
- SILVA, F. A. M.; ASSAD, E. D.; EVANGELISTA, B. A. Caracterização Climática do Bioma Cerrado. In: SANO, S. M.; ALMEIDA, S. P.; RIBEIRO, J. F. (Ed.). **Cerrado: Ecologia e Flora**. Planaltina: Embrapa, 2008. p. 69-87.
- SILVA, R. R.; FREITAS, G. A.; SIEBENEICHLER, S. C.; MATA, J. F.; CHAGAS, J. R. Desenvolvimento inicial de plântulas de *Theobroma grandiflorum* (Willd. ex Spreng.) Schum. sob influência de sombreamento. **Acta Amazonica**, Manaus, v. 7, n. 3, p. 365-370, 2007.
- SOUCHIE, F. F.; MARIMON-JÚNIOR, B. H.; PETTER, F. A.; MADARI, B. E.; MARIMON, B. S.; LENZA, E. **Ciência Florestal**, Santa Maria, v. 21, n. 4, p. 811-821, 2011.
- WHATLEY, J. M.; WHATLEY, F. R. **A luz e a vida das plantas**. São Paulo: EPU-EDUSP, 1982. 101 p.

Recebido em 13/05/2013

Aceito para publicação em 27/01/2014

